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An Update on 34-m Beam-Waveguide Antenna Strut Shaping: Results for Four Strut Shields

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ABSTRACT. — In a previous article, theoretical and experimental results were presented for the performance of a pair of strut shields designed to reduce the ground scatter from 34-m beam-waveguide antenna struts at low elevation angle. While the motivation for adding these shields was reduction of the ground scatter during 7.2-GHz uplink operation at 80 kW, a beneficial reduction in antenna noise temperature was also realized at low elevation angles, as expected. In addition, a somewhat unexpected but beneficial reduction in antenna noise temperature near zenith was also observed. This led to the addition of a second set of shields on the two remaining struts and experimental measurement of the zenith ground scatter, as well as a second set of noise temperature data. These four-shield results are described in this article.

I. Introduction

As discussed in [1], future implementation plans call for the addition of an 80-kW, 7.2-GHz uplink capability for some of the 34-m beam-waveguide (BWG) antennas in the Deep Space Network (DSN). One of these antennas, DSS-26 at Goldstone, is depicted in Figure 1. The purpose for this upgrade is to provide a backup uplink capability that is equivalent to the existing 20-kW uplink on the 70-m antennas.

Previously, work described in [2] was done to reduce the ground scatter from these antennas at low elevation angles. This effort was primarily focused on reducing the ground power density when the high-power transmitter is operating. However, because of reciprocity, reduction of the ground scatter when transmitting also implies less visibility of the ground when receiving, which in turn translates into less thermal noise received from the 290-K ground.

As described in [2], after a set of theoretical calculations and design iterations was completed, a pair of strut shields was added to the top pair of struts at DSS-26 and direct ground scatter measurements were made with the antenna pointed at low elevation angles. These

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Figure 1. DSS-126 34-m BWG antenna.

results confirmed the elimination of the primary ground lobes. Additionally, a tipping curve was measured, showing antenna noise contribution versus antenna elevation angle. These measurements confirmed a reduction in noise pickup at low elevation angles, but also at all other elevation angles, including zenith.

While models predicted the reduction in noise at low elevation angles, the reduction at zenith was unexpected and not predicted from the models. Nevertheless, at zenith all four struts should contribute equally to the ground scatter. This implies that an additional reduction in zenith ground scatter, and thus noise temperature, should be obtained through the addition of two more strut shields on the bottom struts.

Thus, a second phase of the strut scatter project was initiated, including a modeling effort, addition of the second pair of strut shields, and measurement of zenith ground scatter and antenna tipping curves. While the modeling effort was inconclusive, the ground scatter measurements and tipping curve verified the effectiveness of the second set of shields in reducing ground scatter at high elevation angles. This article describes the results of the four-strut-shield configuration at DSS-26.

II. Summary of Previous Two-Shield Results

In this section, we provide a brief summary of the two-shield results. For more detail, see the complete report [2]. In the previous work, the focus was on the reduction of the ground scatter while the antenna is pointed at low elevation angles. This scatter appears predominantly in two lobes and is caused by unwanted scattering off the struts that support the antenna secondary. These struts are depicted in Figure 2, which shows the struts and secondary as they would appear when looking into the structure when the antenna is at low elevation angles. The top struts are shown with their respective proposed shields.

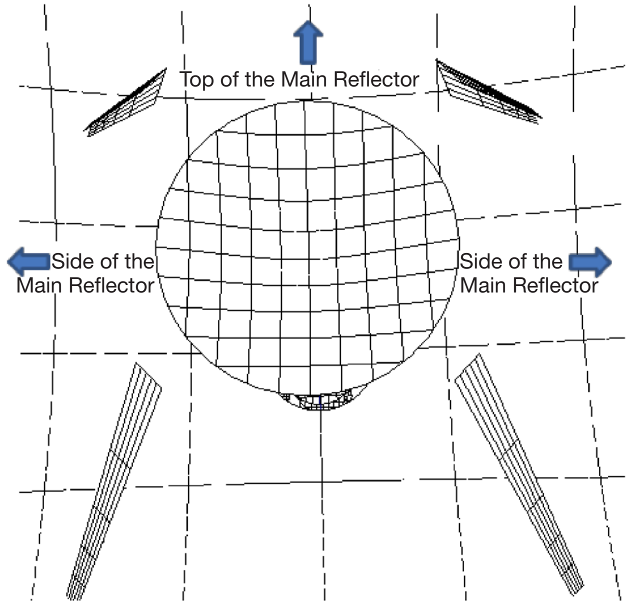

Figure 2. Strut configuration at low elevation angles, looking into the primary with shields shown covering top two struts.

Numerical models of the antenna scattering were created and computations of the ground scatter were undertaken. It was found that the main contributors to the ground scatter were the three mechanisms shown in Figure 3. These include direct scatter of the feed radiation off the top two struts, R1, scattering of the secondary pattern off the strut and then off the primary, R2, and direct feed radiation to the ground, R3.

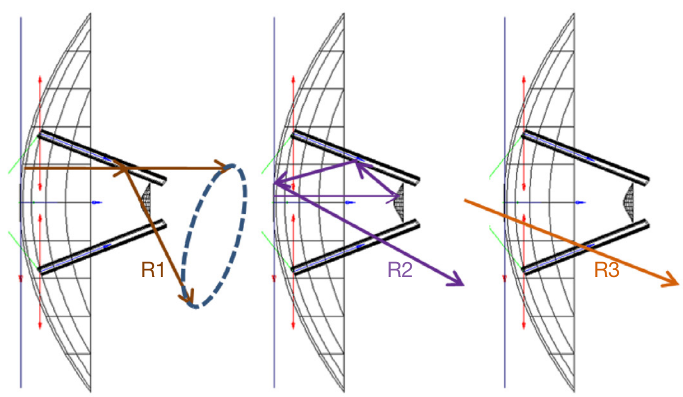

Figure 3. Important scattering mechanisms at low elevation angles.

An important feature of these scattering mechanisms is that they do not involve the bottom pair of struts, and treatments may be applied to only the top pair and still be completely effective at reducing the ground scatter at low antenna elevation angles.

Once the mechanisms were identified, a simple strut shield with an optimum wedge angle was designed, and a pair of these shields were installed on the top two struts on DSS-26 [2].

Direct measurements of the ground scatter confirmed the effectiveness of the shields in reducing the levels, essentially eliminating the primary lobes.

At the conclusion of the ground scatter measurements, a tipping curve — antenna noise contribution versus antenna elevation angle — was measured (Figure 4) and compared to the no-shield configuration. As expected, the antenna noise contribution at low elevation angles (10–30 deg) was significantly reduced since the primary ground lobes were eliminated by the strut shields. Interestingly, the noise was reduced for all elevation angles, including zenith, 90 deg. This result was not predicted by the scatter models of Figure 3, and indicates that other scatter mechanisms are in play for higher elevation angles. The measurements indicate that whatever these mechanisms, they are mitigated by the addition of the shields. In particular, for zenith the symmetry of the situation implies that if two shields provide a reduction of 0.5 K, addition of a second set on the lower struts should provide an additional 0.5 K reduction at zenith. With this in mind, a second modeling and experimental phase, involving the second set of shields, was undertaken. This is the subject of the next section.

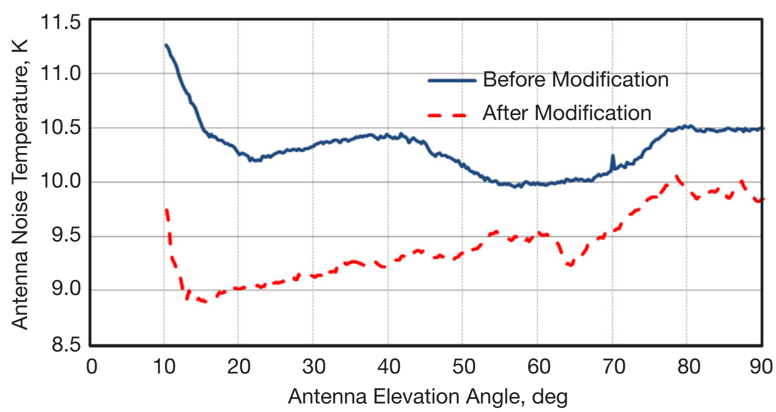

Figure 4. Antenna noise temperature versus elevation angle, before and after the addition of the two strut shields.

III. Summary of New Four-Shield Results

A modeling effort was begun to identify the scattering mechanisms that were important at zenith. This included adding additional scattering paths and including additional scattering structures in the model. Unfortunately, no model was successful in predicting the noise performance shown in Figure 4. Complex scattering paths, including the struts and plates connecting the struts to the secondary, are possible sources of the near-zenith backscatter that is influenced by the struts. This issue remains unresolved at this time.

After efforts to model the situation were unsuccessful, it was decided to proceed on an experimental basis, adding the two remaining strut shields, measuring the ground scatter at zenith, and also measuring a new tipping curve. Fortunately, during the original installation of the first pair of strut shields, four complete shields were fabricated. This made the addition of a second pair of shields possible in a relatively short period of time. Figure 5 shows a view of the four struts on DSS-26 with all shields installed.

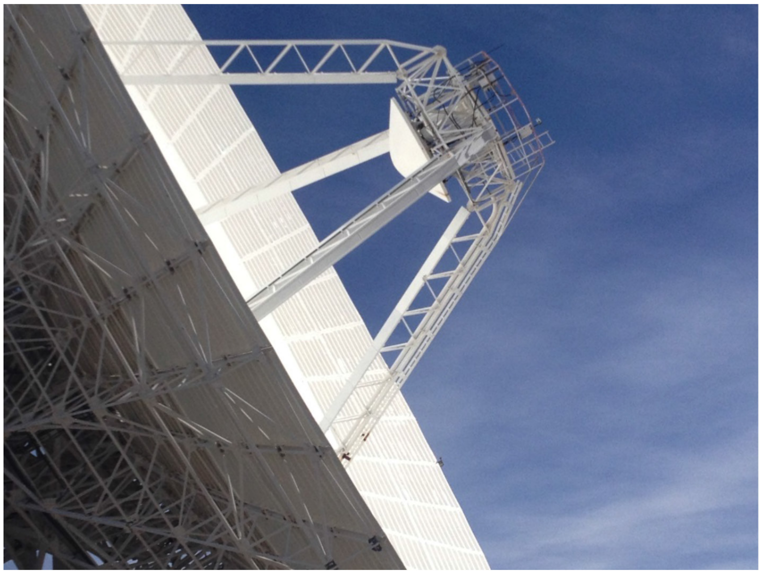

Figure 5. Close-up view of the four strut shields on DSS-26.

The first measurement that was completed was a direct measurement of the ground scatter with the antenna at zenith, prior to installation of the second set of shields. The parameters for this measurement were identical to that of [2], with the exception of antenna elevation. The purpose of this measurement was to establish the signature of the ground scatter responsible for the antenna noise contribution at zenith. Many difficulties related to interference from the other ground stations in the Apollo valley were encountered. On the last attempt, it was possible to measure slightly more than half the ground pattern with no interference. Using the symmetry of the antenna structure that pattern was mirrored to assemble a complete 360-deg pattern (Figure 6). Because of time constraints, only a low-resolution measurement was possible during the allotted antenna time. Of interest are the center area, which is scatter past the primary; a ring of scatter produced from the secondary; and radial spokes produced by an unidentified scattering mechanism that involves the struts. Though not measured, we assume that a zenith ground scatter measurement prior to the installation of the first pair of strut shields would show a symmetrically located set of radial spokes on the opposite side of the pattern. Based on the tipping curve of Figure 4, this radial spoke part of the pattern is responsible for approximately 0.7 K of antenna noise temperature.

A second measurement sequence took place after the installation of the second pair of shields. The ground scatter pattern was measured again, at high resolution (Figure 7). As expected, the radial portions of the pattern are absent, with the remainder largely unchanged. Based on this signature, it is believed that the bulk of the ground scatter produced by the struts has now been eliminated with the use of four strut shields.

The actual measurement points are depicted in Figure 8. As in [2], these were obtained by continuously rotating the antenna in azimuth and driving a vehicle containing a radiation probe back and forth along the access road to the antenna.

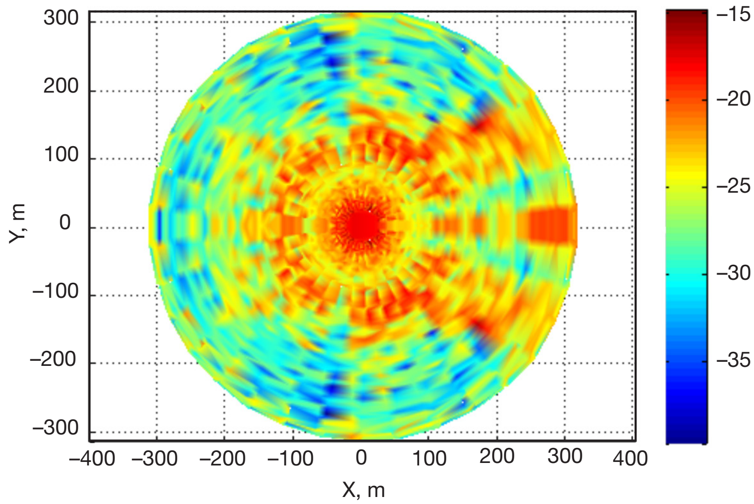

Figure 6. Measured low-resolution zenith ground scatter pattern with two strut shields.

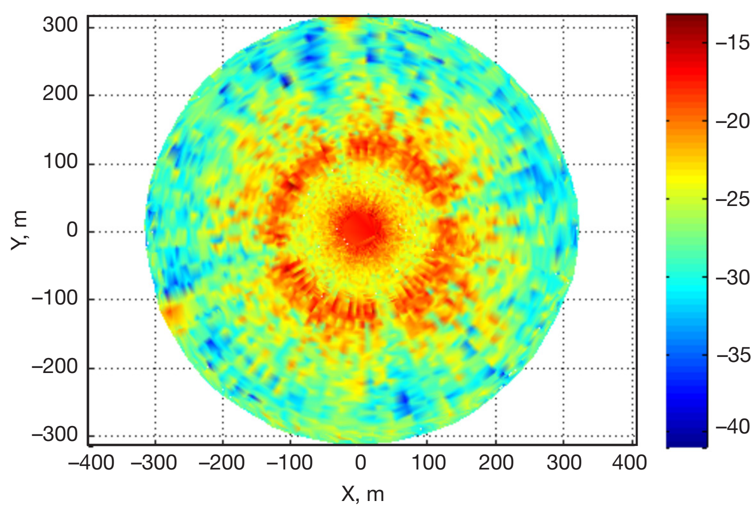

Figure 7. Measured high-resolution zenith ground scatter pattern with four strut shields.

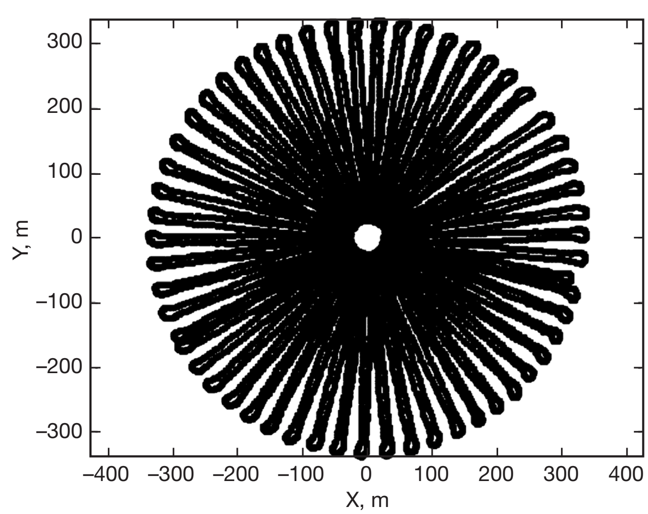

Figure 8. Scan pattern for zenith ground scatter measurements.

Prior to addition of the two shields, a tipping curve for the two-shield case was measured as a reference (Figure 9). In comparing this curve to the curve taken years earlier (Figure 4), we note that there is a fixed offset of approximately 4 K. Attempts were made to resolve this discrepancy, investigating system changes, processing errors, and calibration errors without success. This new baseline curve is used as a basis for comparison with the new four-shield data, which were taken within several days elapsed time (Figure 10).

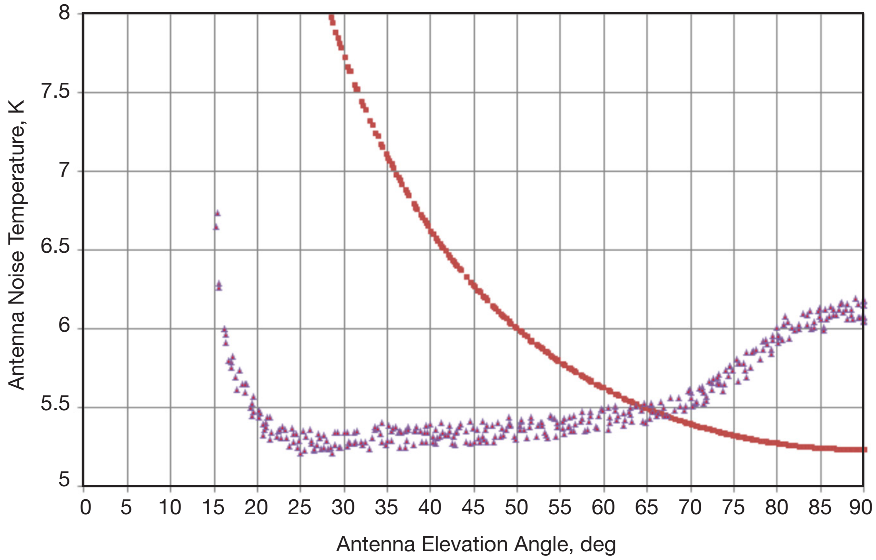

Figure 9. Second measurement of antenna noise versus elevation angle with two strut shields.

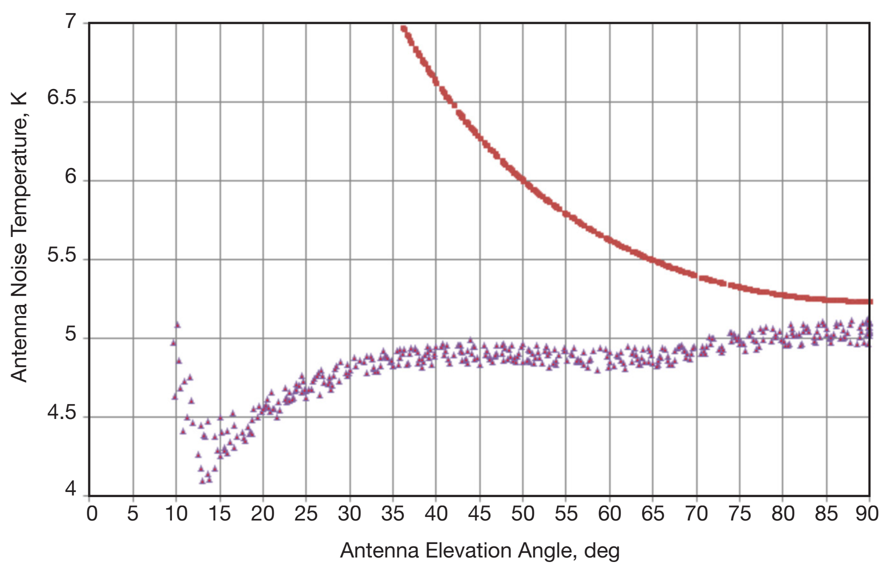

Figure 10. Measurement of antenna noise versus elevation angle with four strut shields.

The tipping curve of Figure 10 shows a reduction in antenna temperature for all elevation angles relative to the two-shield case. At zenith, 90 deg, a reduction of approximately 1 K is seen, slightly better than the 0.7 K predication based on previous measurements. For mid-elevation angles, the reduction is approximately 0.5 K. Overall, a very desirable flat noise versus elevation response is achieved.

IV. Conclusion

Based upon the successful implementation of two strut shields on DSS-26, a follow-up experiment adding the second set of shields was carried out. Though modeling attempts were largely unsuccessful, the experimental measurements demonstrate the benefits of adding the second set of shields. With all four shields installed, a reduction in antenna noise across all elevation angles is achieved and troublesome ground scatter during high power transmission is largely eliminated. Future implementation plans call for the installation of a complete set of shields on all DSN 34-m BWG antennas in the future.

Acknowledgments

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References

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[2] B. Khayatian, D. J. Hoppe, M. J. Britcliffe, and E. Gama, "Reducing Near-Field RF Levels and Noise Temperature on a 34-m Beam-Waveguide Antenna by Strut Shaping," *The Interplanetary Network Progress Report*, vol. 42-192, Jet Propulsion Laboratory, Pasadena, California, pp. 1–9, February 15, 2013.
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